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WASTE POL DISPOSAL THROUGH ENERGY RECOVERY.(U)
JUN 76 P T FINK , J W JACKSON
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# WASTE POL DISPOSAL THROUGH ENERGY RECOVERY

JUNE 1976



FINAL REPORT: FEBRUARY 1974 - JUNE 1976

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AIR FORCE CIVIL ENGINEERING CENTER
(AIR FORCE SYSTEMS COMMAND)
TYNDALL AIR FORCE BASE
FLORIDA 32401

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In order to investigate the practical feasibility of combusting waste POLS (petroleum, oil, lubricants) in heating plant boilers, a field testing program was undertaken to obtain actual performance and air pollution data. Since most Air Force heating plants utilize FS-Grade (No 2, No 5) fuel or natural gas as a primary fuel source, emphasis was placed on the installation of waste POL systems at three separate Air Force bases employing the use of these fuels. Various percentages of waste POL were burned in the test boilers with the →




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20. Abstract (continued)

corresponding fluctuation in stack emissions documented. Results of this study are reported in terms of quantity and hours of waste POL burned per installation, operational procedures, air pollution data, and recommendations for the safe installation of a compatible waste POL system.

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# PREFACE

This report was prepared by the Air Force Civil Engineering Center, Tyndall Air Force Base, Florida, under Job Order Number 20543W10. The design drawings for the Waste POL System were prepared by Arthur D. Little, Inc.

This report documents the work completed between 1 February 1974 and 1 June 1976. First Lieutenant Patrick T. Fink was project engineer and author, and Captain Jerry W. Jackson, EHL-McClellan Air Force Base, California, was coauthor.

The author wishes to thank the military and civilian personnel associated with the Waste POL project from SAC and TAC for their support and timely assistance. The author also acknowledges the technical assistance contributed by Capt Dean D. Nelson, AFCEC.

This report has been reviewed by the Information Officer (IO) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public.

This report has been reviewed and is approved for publication.

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# SECTION I

## INTRODUCTION

Over the past few decades, the growing complexity and diversity of Air Force operations have contributed to an increase in the quantity of waste POLs (petroleum, oils, lubricants) generated. Stringent environmental legislation directed at the limitation and eventual elimination of point and continuous discharges of contaminants into a water or air medium have compelled the methods of disposal of waste of POLs by incineration or biological treatment to become unacceptable. With present Department of Defense (DoD) emphasis on energy conservation and reclamation, the recovery of waste POLs through supplemental combustion in heating plant boilers provides a far more practical avenue for disposal and eventual monetary return than through resale by the local Defense Property Disposal Office.

Since the vast majority of waste POLs are petroleum distillates by composition, their composite heating properties; viscosity, heating value (Btu/lb), and flashpoint, allow the compatible utilization as a supplementary heating fuel provided adequate attention is given to waste segregation prior to storage (Reference Technical Order 42B-1-23, Segregation of Used Fuel and Oils). When you consider the millions of gallons per year of contaminated fuels and lubricants generated on Air Force bases (1.4 million gallons on TAC bases alone, Reference 1), the concept of waste POL reuse should be considered as paramount for disposal of spent fuels. Since the Btu content of waste POL approximates that of No. 2 or No. 5 fuel oil (140,500 Btu/lb), the combustion of 1 gallon of waste POL saves 1 gallon of fuel oil for a monetary savings of \$0.35 to \$0.45 per gallon. In addition to the monetary savings, the substitution of a high sulfur FS-grade fuel with a low sulfur volatile fuel such as JP-4, results in a reduction of certain stack emissions and more complete combustion which has a definite impact on the quality of the ambient air.

It is the objective of this technical report to investigate the practical feasibility of combusting waste POLs in heating plant boilers using various combinations

of heating fuels while insuring a safe, long-term system, free of operational or storage problems.

In order to study the long-term effects of waste POL combustion such as corrosion, concentration of emissions, heat transfer, etc., and to culminate in a practical, cost effective system for implementation, three test bases with boiler capacities and fuel source listed below were selected because the results would be applicable to many USAF installations:

1. Loring AFB, ME (>50 MBtu/hr input) using a high grade fuel (No. 2 fuel oil).

2. Seymour Johnson AFB, SC (<50 MBtu but >20 MBtu/hr) using a low grade fuel (No. 5 fuel oil).

3. McConnell AFB, KS (<20 MBtu/hr input) using a high grade fuel (natural gas and/or No. 2 fuel oil).

The research conducted in support of this effort was designed to produce a practical waste POL disposal system capable of implementation.

SECTION II

DESCRIPTION OF EXISTING FACILITIES

## 1. LORING AFB

The primary function of the main heating plant is to provide steam which is used to heat water for circulation around Loring. This plant is composed of six 72,875 lb/hr (output 63 MBtu/hr) boilers, three of which operate exclusively on coal. The remaining three boilers utilize No. 2 fuel oil after conversion from coal. All are water tube boilers using steam atomization as a firing mechanism. The average age of the boilers is 22 years.

The boiler specifically modified to accommodate the waste POL system is manufactured by the Wickes Boiler Company. This unit is a high temperature hot water system (HTHW), double drum, bent tube "R" type with four burners rated at 1200 lb/hr (No. 2 fuel oil) each. The burners are manufactured by the Peabody Company. The operating steam/air pressure is 125 psig while the fuel pressure is 105 psig. As previously noted, the boiler uses steam-atomization for fuel delivery.

## 2. SEYMOUR JOHNSON AFB

The main heating plant where waste POL testing was conducted is centrally located on Seymour Johnson AFB. This facility consists of two 15,000 lb/hr and two 25,000 lb/hr steam boilers that use No. 5 fuel oil as a primary heating fuel source. All four boilers employ air and heat atomization as the method of boiler firing. The larger boilers were constructed in 1957 while the two smaller units were added to the facility in 1967. A conversion from coal to FS-grade fuels occurred in 1972.

The specific boiler used in the testing was manufactured by the Bigelow Company. The unit is a water tube type with a maximum steam capacity of 19.3 MBtu/hr. The maximum fuel capacity of the burner is 1034 lb/hr of No. 5 fuel oil with a fuel operating pressure of 31.5 psig at 158°F. The burner is manufactured by Power Flame, Inc.

3. McCONNELL AFB

The site selected for use as a test facility was building 1106, adjacent to the flight line. This heating plant consists of three 260-hp and one 98-hp boilers. All four boilers are of the water tube type which use natural gas or No. 2 fuel oil as a fuel source. Since this system is designed to operate in either mode but not simultaneously, a special loop piping network on the No. 2 line allows instantaneous termination of No. 2 fuel oil flow and subsequent recycling back to the storage tank.

The test boiler identified for modification was manufactured by the Kewanee Boiler Corporation. As previously noted, the unit is a fire tube type with a maximum steam capacity of 11,000 lb/hr (8.74 MBtu/hr). The boiler uses a singular burner for combustion which possesses a maximum flow rate for No. 2 fuel oil of 100 gal/hr and an average natural gas flow rate of 7.2 x 10 scf/mo. The ARC-134, rotary cup burners, were manufactured by the Ray Oil Burner Company. The No. 2 fuel oil pressure is 15 psig at 158°F.

## SECTION III

## DESCRIPTION OF WASTE POL SYSTEMS

### 1. GENERAL

The Waste POL Transfer System is similar at the three bases; i.e., Seymour Johnson, Loring, and McConnell AFBs with the variations due to different fuel controls presently employed on the boilers and whether the Waste POL Transfer System is manual or automatic (Reference 2). Conceptual waste POL flow and control diagrams are contained in Appendices A & B.

All waste POL systems constructed at the three test facilities contained two tanks. One for contaminated JP-4 and one for waste lubricants, oils, solvents, etc. that were installed outside each heating plant. Local safety considerations such as proximity to heavily traveled areas (parking lots or facilities), expected unloading practices, and fire codes dictated whether the tanks were to be installed above- or belowground level. Each tank contained a Petrometer® gauge and low-level liquid indicator. If the fluid level in either storage vessel drops below the low-level limit, a relay switch is activated terminating current to the positive displacement pump and de-energizing the solenoid valves at the burner. Since both lines are wired in series, the entire system is deactivated pending additional waste fuel or appropriate valving to allow for extraction of waste POLs from a singular tank. All aboveground storage tanks contain a drain valve for gravity removal of sediment while those installed subsurface must be evacuated by a pump providing adequate suction lift.

The network piping system from the storage vessels to the boilers consists of an assortment of valves, filters, and a duplex, positive displacement pump. After the waste POL has left the tank, an in-line strainer-filter combination is designed to eliminate sediment and impurities so that there is no detrimental effect on the pump seals. A 12 gph duplex pump with a suction lift of 8 feet dry and 24 feet primed, discharges waste POL through a 3/4-inch piping system and conglomeration of valves to the burner. The duplex pumps can be independently regulated

to adjust the flow rate of waste POL to the burner. Mixing of waste POLs is accomplished as close to the boiler as possible to minimize both the lag time involved prior to combustion and the exposure time of JP-4 with other fuels due to its low vapor pressure (1.5 psia). All piping used in the waste POL system was Schedule 80 iron pipe comparable to that used for JP-4 storage and delivery and natural gas operations.

2. LORING AFB

a. Fuel System

The Waste POL System constructed at Loring AFB (Figures 1 and 2) consisted of two steel tanks, a 5000 gallon tank for JP-4 and a 3000 gallon tank for waste lubricants and oils (Figure 3), a duplex plunger type pump(s) (Figure 4), and a series of valves for separate line isolation. The two storage tanks were installed approximately 25 feet from the periphery of the heater plant. A header pipe was installed on both the suction and discharge side of the pumps allowing the use of either or both tanks by either or both pumps, thus providing good operational flexibility.

In this case, waste POLs were gravity fed from the storage tanks to the pumps which were installed inside the heating plant (Figure 4). Safety relief valves were installed across each pump and designed to open at 250 psig. Filtering is accomplished inside the plant before entrance to the pumps. High and low level pressure switches were installed after the pump with cutoff pressures of 240 psig and 75 psig, respectively. A sight glass connected in series between both switches provides verification of flow.

Before mixing with No. 2 fuel oil near the entrance to burner No. 4, the waste POL passes through a series of check, gate, and solenoid valves which are designed to prohibit waste POL flow. In the case of a system malfunction, the check valve prevents backflow should the No. 2 fuel line pressure exceed the waste POL line pressure while the gate valves manually throttle or terminate flow. The 115 VAC solenoid valve is electrically operated and either permits or prohibits flow of waste POLs. It is tied directly into the pump control relay affording complete shutdown of the system in the event of a malfunction.

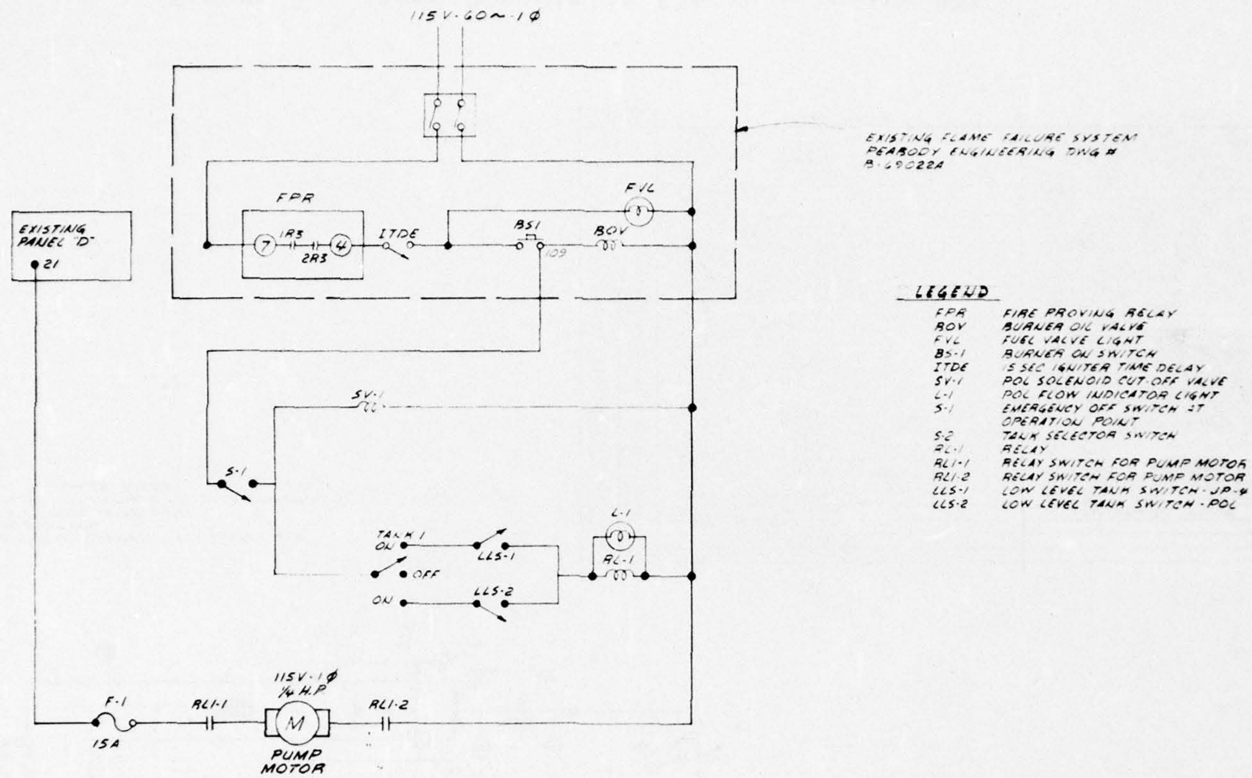
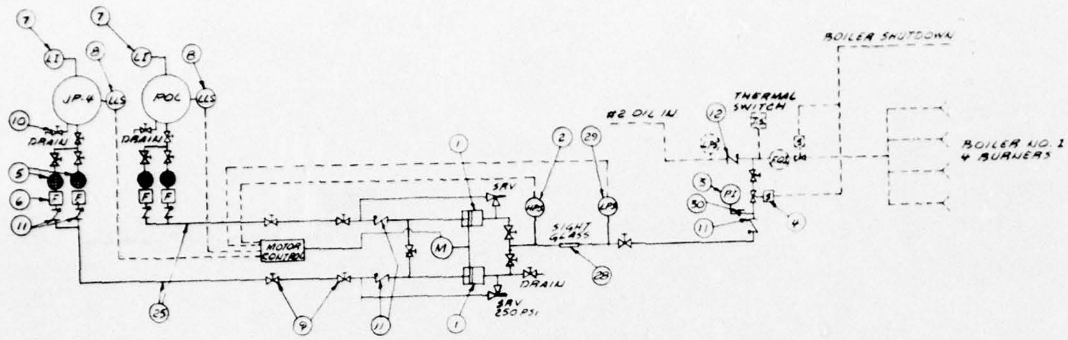



Figure 1. Waste POL Control Circuit - Loring AFB




NOTES
1. FOR ELECTRICAL SCHEMATIC SEE SHEET 1 OF 2
2. ALL PIPING 300# MIN
3. SUPPORT ALL PIPING AS REQUIRED
4. USE 3/4 SCH 80 PIPE BETWEEN POL TANKS + PUMP
5. PAINT ALL POL LINES YELLOW

| ITEM NO | QTY REQD | DESCRIPTION | MATERIAL |
|---|---|---|---|
| 30 | 1 | DRAIN COCK | |
| 29 | 1 | LOW PRESSURE SWITCH | |
| 28 | 1 | SIGHT GLASS | |
| 27 | 10 | REDUCING COUPLING | 3/4" x 3/8" SCH 80 300# |
| 26 | 10 | REDUCING BUSHING | 3/4 x 3/8" SCH 80 300# |
| 25 | 400FT | PIPE | 3/4" SCH 80 IRON (SEE NOTE 4) |
| 24 | 10 | UNION 300# | 3/4" NPTF MALLEABLE IRON |
| 23 | 40 | COUPLING 300# | 3/4" NPTF " " |
| 22 | 10 | TEE 300# | 3/4" NPTF " " |
| 21 | 25 | ELBOW 300# | 3/4" NPT x 90° MALLEABLE IRON |
| 20 | 6 | COUPLING 300# | 3/8" NPTF MALLEABLE IRON |
| 19 | 12 | NIPPLE | 3/8" NPT x 2" LONG SCH 80 MALLEABLE IRON |
| 18 | 2 | STREET ELBOW | 3/8" NPT x 90° MALLEABLE IRON |
| 17 | 4 | REDUCING BUSHING | 1/2" NPTM x 3/8" NPTF MALLEABLE IRON |
| 16 | 10 | TEE 300# | 3/8" NPT MALLEABLE IRON |
| 15 | 12 | ELBOW 300# | 3/8" NPTF x 90° MALLEABLE IRON |
| 14 | 6 | UNION 300# | 3/8" NPTF |
| 13 | 30FT | PIPE | 3/8" SCH 80 IRON |
| 12 | 1 | CHECK VALVE 300# | REX ROTH S30A1-5 |
| 11 | 7 | CHECK VALVE 300# | REX ROTH S8A-[illegible]-5 3/8" |
| 10 | 8 | MANUAL 2 WAY VALVE | SALISBURY FIG 350 1" |
| 9 | 10 | MANUAL 2-WAY VALVE | DRAGON 5005 3/8" 300# |
| 8 | 2 | OIL LEVEL SWITCH | McDONNELL + MILLER INC. NO. 80 |
| 7 | 2 | OIL LEVEL GAUGE | PETROMETER CORP 1329 |
| 6 | 4 | FILTER | FULLFLOW F88 3/8" |
| 5 | 4 | STRAINER | KRAISSL CO 1" SIMPLEX |
| 4 | 1 | SOLENOID VALVE | I.T.T. S-401 XF-04L3CF5 |
| 3 | 1 | PRESSURE GAUGE | MARSH, 0 TO 300 PSI 2½ GLYCERINE FILLED |
| 2 | 1 | PRESSURE SWITCH | BARKSDALE, C-9612-1, 300 PSI |
| 1 | 1 | PUMP | T.X.T. 14175C2P2 |

Figure 2. Waste POL Piping Scheme - Loring AFB

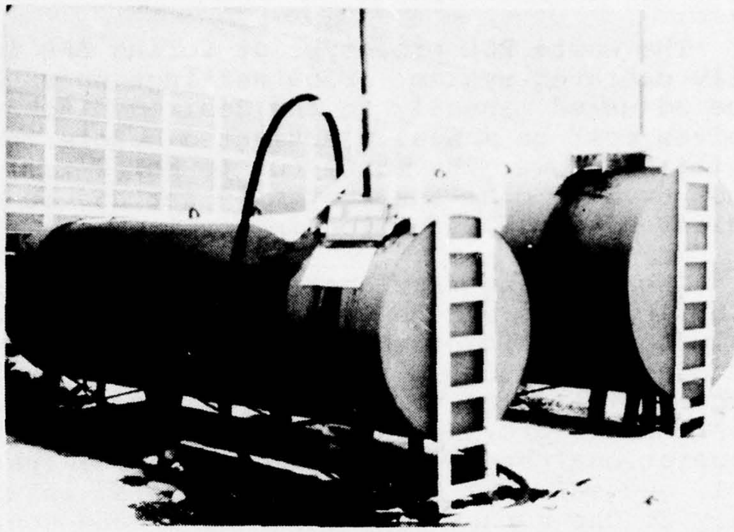


Figure 3. Storage Vessels - Loring AFB

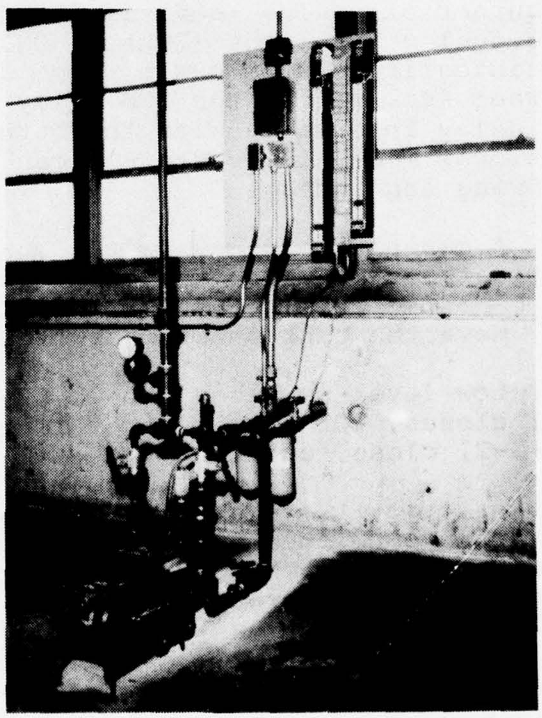


Figure 4. Duplex Pump Installation - Loring AFB

b. Flow Control System

The waste POL prototype at Loring AFB is a manually operated system. Flow settings on each pump must be adjusted manually to the desired discharge rate. All valves must be manually activated before the system can initiate flow. The waste POL to No. 2 fuel ratio will not deviate once the system is set and in operation, regardless of any fluctuation in steam pressure.

The existing flow control system for the heating plant boilers uses a Honeywell Protectorelay® Model R-485A. A schematic of this system is shown as a dashed line in Figure 1. The flame proving relay (FPR), integrated time delay (ITD), and additional circuitry are designed to provide automatic sequence control for such operational stages as purge, start-up, system control, and safety. The Waste POL System is wired directly to the burner ON switch (BS-1) and control panel D (Burner No. 4) and is provided with safety measures identical to the main system. This system is wired so that no waste POL can be transfered to the No. 2 level line until the purge cycle is complete, FPR is activated, burner oil valve (BOV) is energized by the BS-1 and the fuel valve light (FVL) is ON. In order to develop the integrity of the purge flame and to manually cock the burner fuel valve, the ITD relay begins a 15-second time delay interval. With the burner now in fully operational mode, the waste POL can be activated in the following sequence:

(1) A manual emergency switch on the control panel is activated energizing the solenoid valve (SV-1).

(2) Move the tank selector switch to ON.

(3) Low-level switches (LL-1, LL-2) close, relay (RL-1) closes, POL supply light is lit, and relays (RL-1-1, RL-1-2) close, engaging the waste POL pump motor.

(4) The No. 2 fuel oil is prevented from entering the POL by a check valve (Item 11, Figure 2) until the waste POL feed pressure exceeds the No. 2 line pressure.

(5) HPS-LPS are tied into RL-1.

Normal shutdown of the waste POL system should be as follows:

(1) Place the tank selector switch to the OFF position.

(2) Close valves to waste POL tank.

(3) Place solenoid valve switch (S-1) to the OFF position.

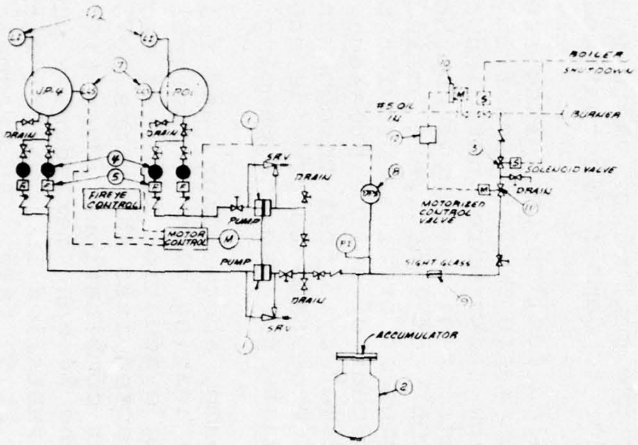
3. SEYMOUR JOHNSON AFB

a. Fuel System

The Waste POL Transfer System at Seymour Johnson (Figures 5, 6 and 7) is similar in conceptual design to the other two test facilities; however, such parameters as site location, safety, plant layout, and operational maintenance procedures substantiates the system's uniqueness. Design modifications to the original A. D. Little drawings were responsible for the addition of drain, gate, and check valves for the control of waste POL distribution as well as accumulator to dampen fluctuations in pressure.

Two 5000-gallon fueling-defueling tanks were obtained for use in the waste POL project from two salvaged vehicles. The storage tanks were installed approximately 50 feet from the exterior elevation of the heating plant (Figure 8). Waste POL feed lines were buried underground in transit to the pumps in order to provide an additional factor of safety in event of a line breakage. Both tanks were elevated approximately 5 feet through the use of cinder block support pedestals to provide enough head for gravity feeding of waste POLs to the pumping unit.

The duplex pump, accumulator, and filters were installed within the heating plant (Figure 9). Waste POL is filtered following evacuation from the storage tanks and before being injected into the pumps by an in-line strainer-cloth filter combination. Once filtered, fuel is introduced into the 24 gph (max) duplex pumps. A safety relief valve installed in parallel with each pump was designed to open at 65 psig. An accumulator was introduced in the system, after the pumps, to dampen any pressure surges while maintaining a relatively constant




| SYM | NO REQD | PART | MANUFACTURER |
|---|---|---|---|
| 1 | 1 | PUMP | [illegible] CP2 |
| 2 | 1 | ACCUMULATOR | GREER, SURGE [illegible] 275KS [illegible] |
| 3 | 1 | SOLENOID VALVE | I.T.T. 5401-XF-05 |
| 4 | 4 | STRAINER | [illegible] |
| 5 | 4 | FILTER | FULLFLOW FBA |
| 6 | 2 | OIL LEVEL GAUGE | PETROMETER CORP. 1329 |
| 7 | 2 | OIL LEVEL SWITCH | McDONNELL & MILLER, INC. NO. 80 |
| 8 | 1 | PRESSURE DIFFERENTIAL SWITCH | [illegible] CORP. [illegible] |
| 9 | 1 | IN-LINE SIGHT GLASS | |
| 10 | 1 | AUXILIARY POT | HONEYWELL [illegible] 1094 |
| 11 | 1 | MOTORIZED CONTROL VALVE | " Q4B1A1007 |
| 12 | 1 | POSITIONING POT | " [illegible]E894FA |
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Figure 5. Waste POL Piping Scheme - Seymour Johnson AFB

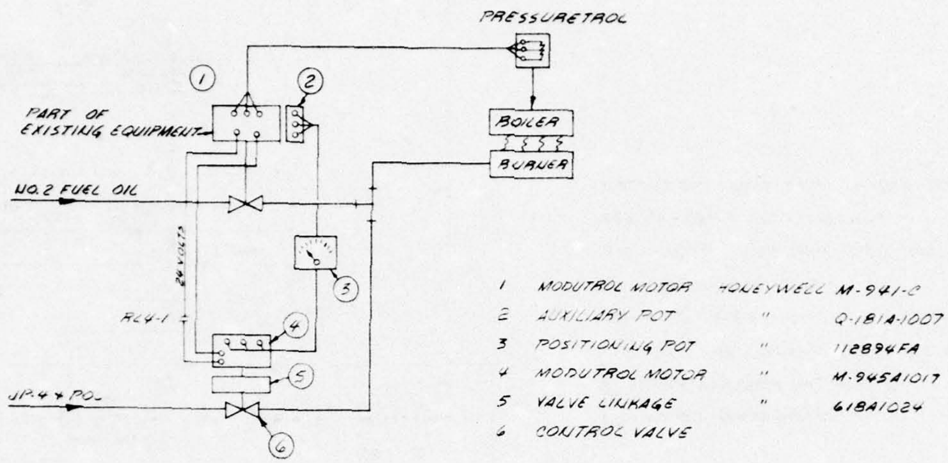



Figure 6. Automatic Ratio Control - Seymour Johnson AFB

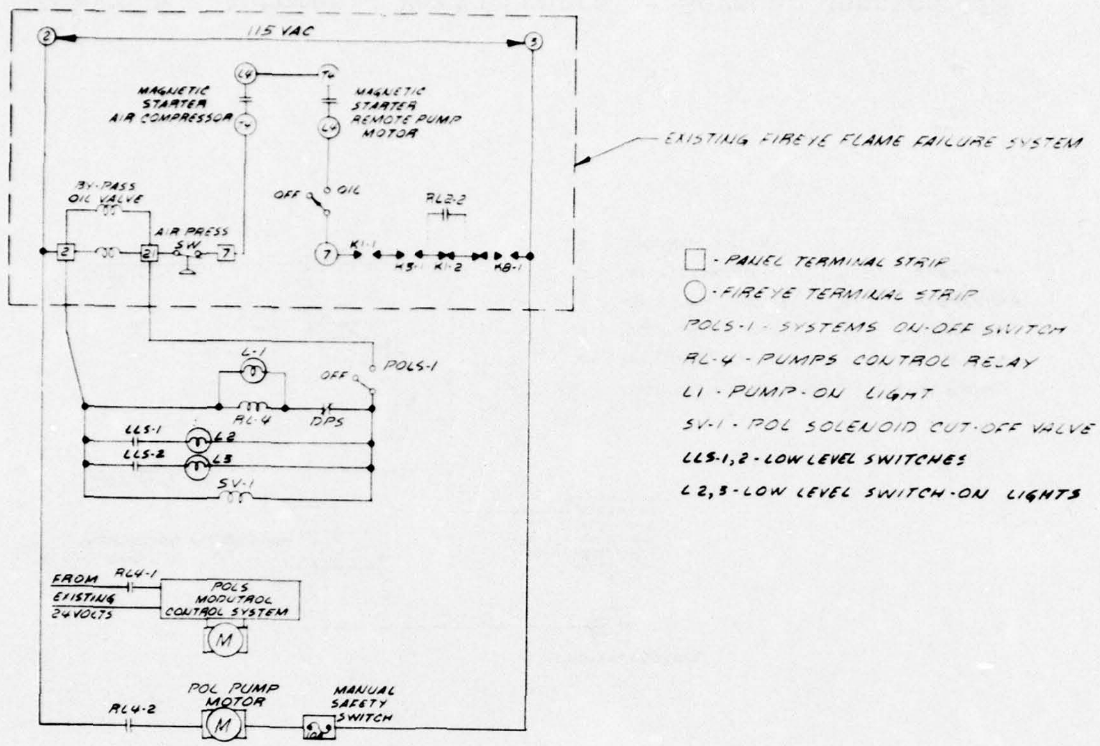



Figure 7. Waste POL Control Circuit - Seymour Johnson AFB

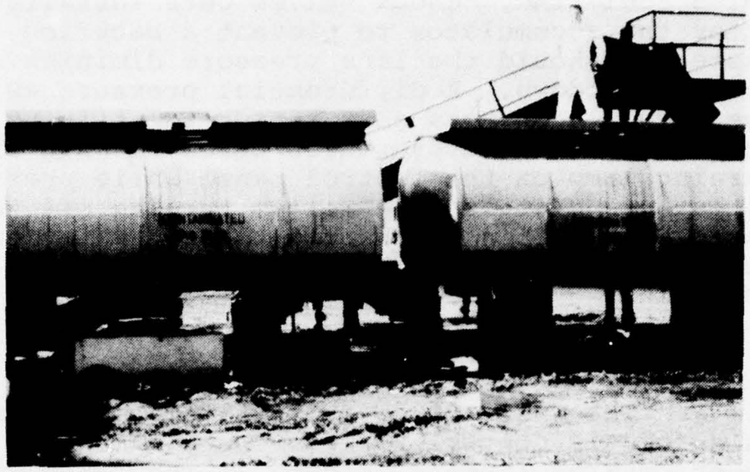


Figure 8. Storage Vessels - Seymour Johnson AFB

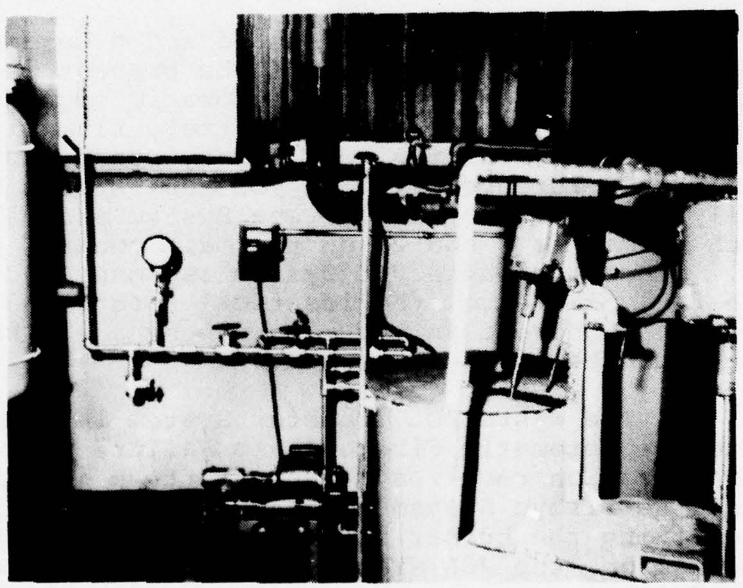


Figure 9. Duplex Pump, Accumulator and Waste POL Piping - Seymour Johnson AFB

waste POL pressure (30 to 45 psig) for injection into the No. 5 fuel line. Check valves were installed before and after the accumulator to prevent a backflow of No. 5 or waste POL should the line pressure diminish causing a system shutdown. A differential pressure switch after the accumulator acts as a sensor identifying fluctuations in pressure. Flow pressures below 30 psig will engage a warning lamp on the control panel while pressures above 45 psig de-energize the relays turning off the pump. Waste POL is then discharged through motor control and solenoid valves which control the flow rates to the main fuel line.

b. Flow Control System

The waste POL system at this installation employs an automatic control for flow regulation. A Modutrol® Motor Control (Item 4, Figure 6) requiring 24 volts is tied directly into the existing Modutrol® Motor (Item 1, Figure 6) and is capable of varying waste POL flow in proportion to the No. 5 fuel flow. The automatic control compensates for a fluctuating No. 5 fuel flow demand by tapering the waste POL concentration maintaining a predetermined ratio.

A Fireye flame safeguard and programming control system is an integral part of the present heating plant control system and provides automatic sequence start-up, flame ignition, operational control, flame ignition control, flame failure, and safety functions for the boilers (Reference 2). The POL test system is electrically controlled by the Fireye System and is interfaced with terminals 2 and 21 on the main control panel (Figure 7). Since the waste POL system is connected directly to the fuel oil valve, the identical safety and operating features inherent in the main system are likewise applicable to the POL test system.

The Waste POL Transfer System is tied directly into the automatic Fireye Flame Failure System; however, its operation requires manual start-up for initiation. Once the Fireye System has started its sequence of energizing the burner motor and completing the purging succession, the POL system can be manually activated in the following manner:

(1) By engaging POLs-1 (Figure 7), the system

is energized. This will open the solenoid valve (SV-1), close relays RL-4, RL-4-1, and RL-4-2; and activate the Modutrol® Control System. Since 24 volts are being transferred to the POL Modutrol® Unit (Item 4, Figure 6) from the main Honeywell Modutrol® System (Item 1, Figure 6), the POL pump motor is activated, providing simultaneous flow with No. 5 fuel.

(2) A pressure differential switch (DPS) (Figure 7) and accumulator (Item 2, Figure 6) maintain a constant pressure between 30 to 45 psig. When the line pressure drops below 30 psig, the DPS will close, Relay RL-4 (Figure 7) will energize, and Lamp L-1 (Figure 7) will light. Relays RL-4-1 and RL-4-2 will close, activating the pumps. If the pressure exceeds 45 psig, the DPS and all relays open, shutting down the waste POL pump. Main boiler shutdown deactivates the solenoid valve (SV-1), terminating waste POL flow.

(3) Low-level switches (LLS-1, LLS-2) and lamps (L-2, L-3) (Figure 7) are installed in parallel with contact points 2 and 21. If the fluid level in either storage tank drops below a predesignated level, the relay LLS-1 or LLS-2 will close, lighting the warning lamp located on the control panel. Immediate action can be taken to switch tanks or add more fuel to the operational tank.

4. McCONNELL AFB

a. Fuel System

The Waste POL Transfer System at McConnell is similar in conceptual design to the other test systems; however, the number of boilers serviced and the construction depicted in this installation vindicates its uniqueness. The complete underground installation of this waste POL system, unlike Loring or Seymour Johnson Air Force Bases, is the most favorable from a storage and transfer viewpoint. The system was modified to accommodate a dual waste POL system suitable for combusting waste fuels in two boilers instead of one, as is prevalent at the other test bases (Figures 10, 11, 12, and 13).

Two 5000-gallon steel tanks were installed underground approximately 150 feet from the heating plant, Building 1106 (Figure 14). Tank vent lines extend 3 to 4 feet above ground level to allow for breathing of fuel

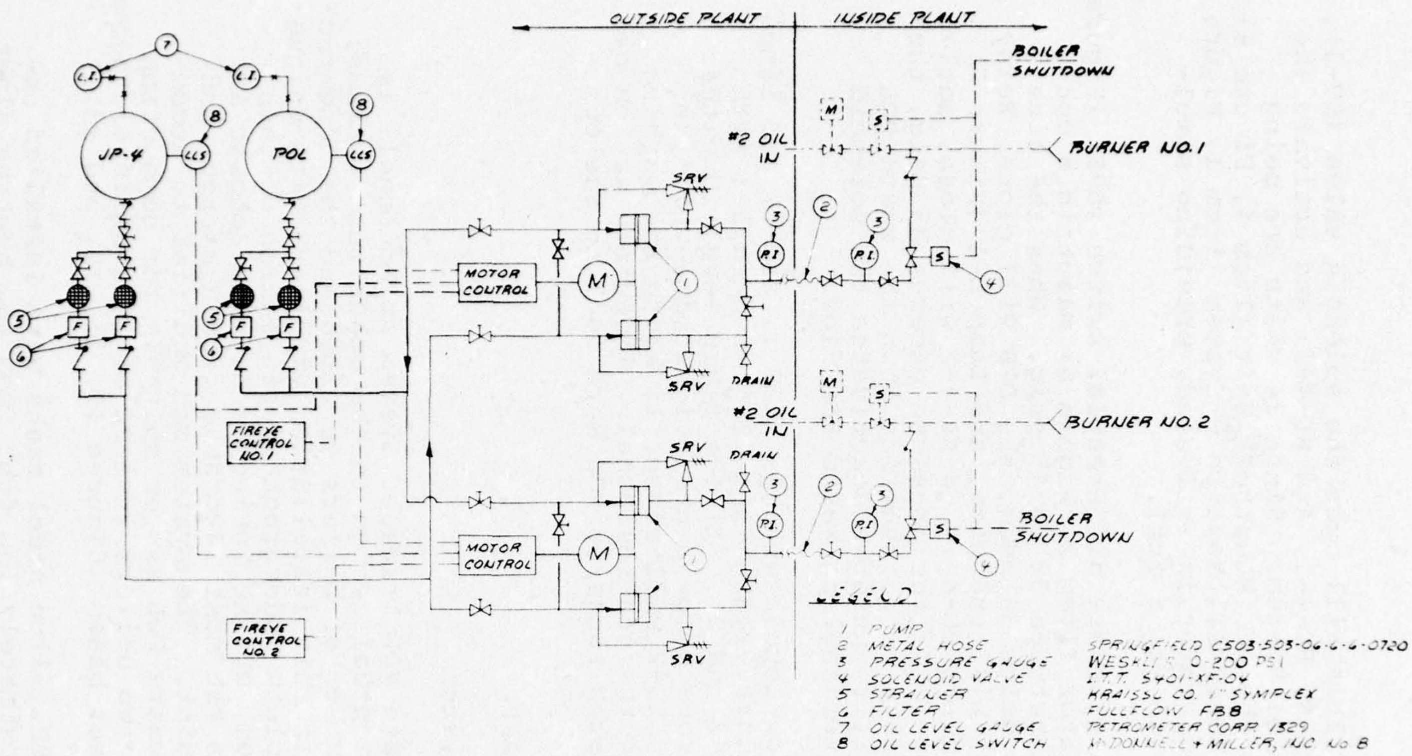
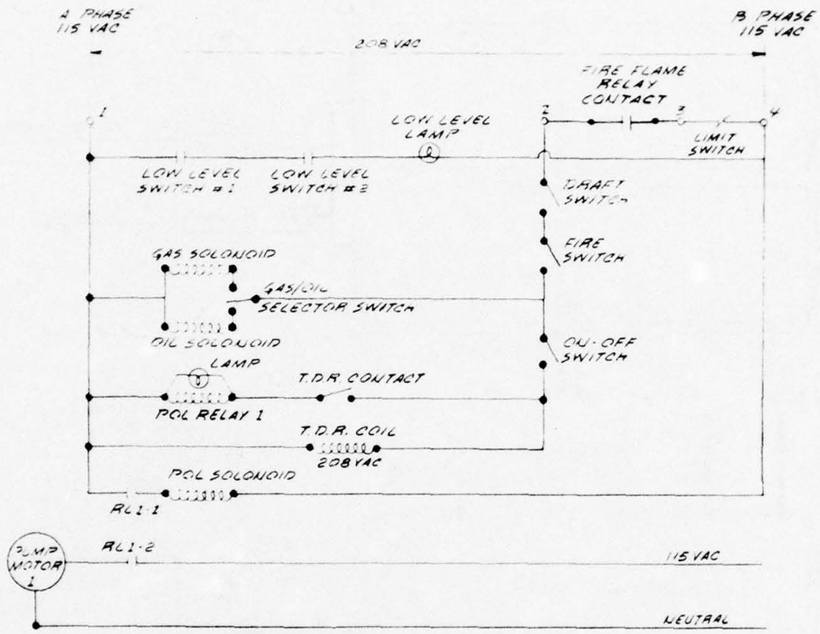



Figure 10. Waste POL Piping Scheme - McConnell AFB




1. LOW LEVEL SWITCHES ARE OPEN WITH LOW FUEL LEVEL
2. CIRCUITRY FOR BOILER #2 AND PUMP #2 IS IDENTICAL

Figure 11. Manual Control Circuit - McConnell AFB

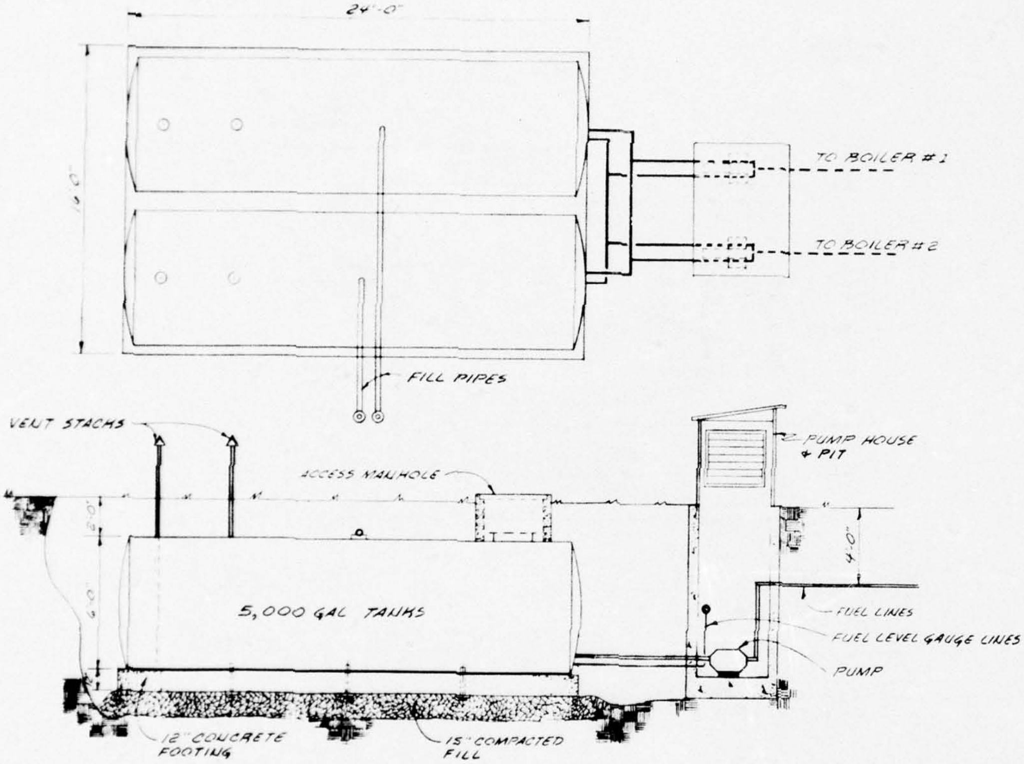



Figure 12. Storage Tank Installation - McConnell AFB

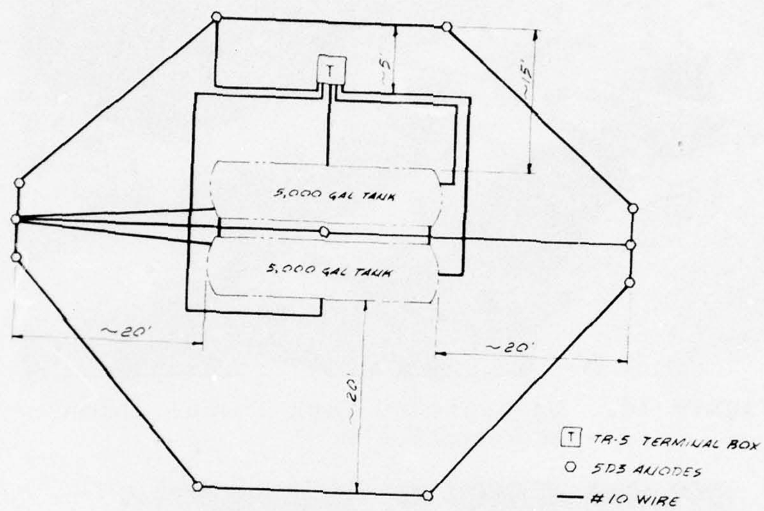



Figure 13. Cathodic Protection Layout
- McConnell AFB

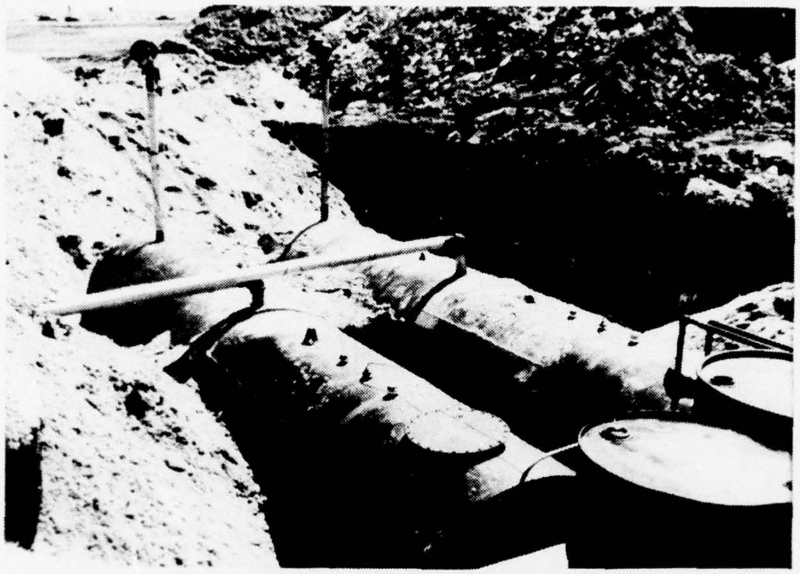


Figure 14. Underground Tank Installation
- McConnell AFB

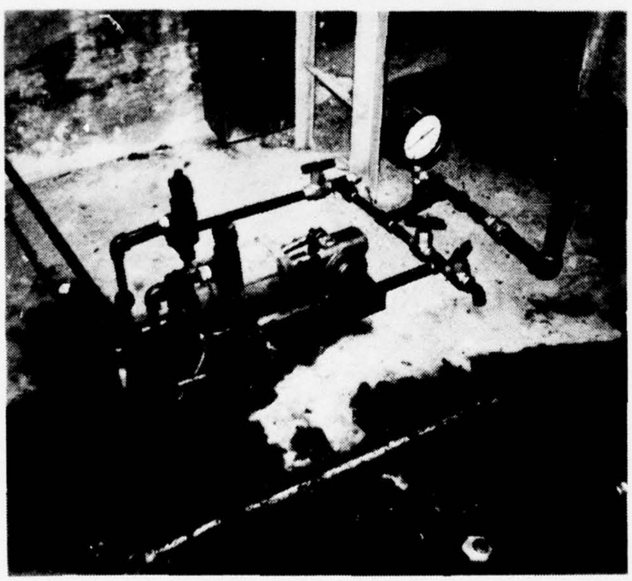


Figure 15. Duplex Pump Installation
- McConnell AFB

and are equipped with bird screening and rain hood to eliminate the possibility of water intrusion. Fill lines were extended 20 feet from the tanks near an adjacent parking lot to take advantage of the accessibility for transfer vehicles.

Waste POL feed from both tanks are gravity fed to the parallel combination of duplex pumps (Figure 10) which were installed in an adjacent pumphouse (Figure 12). Initial field testing with the pumps at ground level revealed the actual suction lift of the pump (8 feet) was less than its net positive suction head (NPSH) so that continuous flow was not achieved. A 10 x 10 x 12 foot concrete pit was constructed with support structure to allow for the lowering of the pumps to the waste POL feed level thus reemploying gravity feed (Figure 15). Both waste POL lines were then filtered with the strainer-filter combination before entrance to the pumps. Each waste POL tank line was split to allow for feed to each duplex pump. In this manner, either or both pumps could draw from a single or both tanks depending on demand. Safety relief valves installed across each side of each pump were designed to open at 50 psig. Due to the excessive run of the feed line to the boilers (Approx. 150 feet), pressure gauges were installed in the pit on the discharge side of each pump and in the heating plant before entrance to the burners.

To optimize the element of safety during installation, all the feed piping to the boilers was installed underground. In an attempt to minimize the possibility of a fuel leak and maximize safety, the fuel lines were buried in the floor slab upon entrance to the heating plant. Waste POL lines exited adjacent to each boiler where the flexible piping connected to a series of gate, solenoid, and check valves designed for immediate termination of flow in event of a malfunction (Figure 16).

b. Flow Control System

The Waste POL System at McConnell AFB employs a manual control for the adjustment of flow rate. The operational difference in this system lies in the small size of the boilers (8.74 MBtu/hr). Since the fuel oil flow varies significantly with seasonal demands, the discharge flow rate from the pumps has to be manually adjusted to maintain a fixed POL flow rate to the burners.

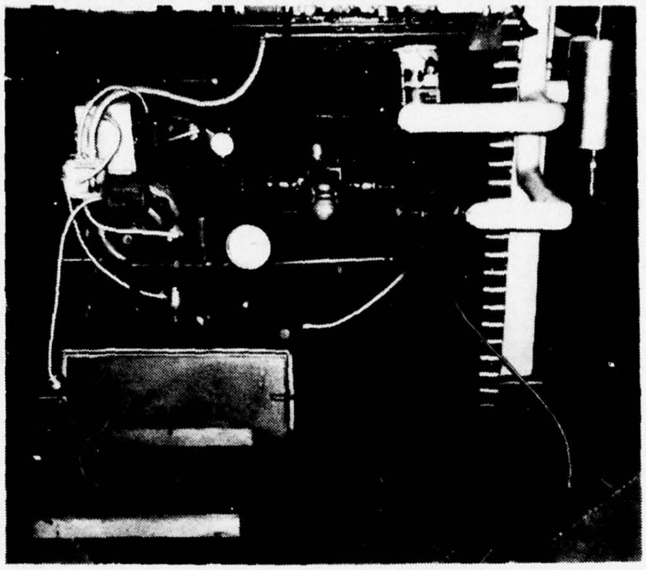


Figure 16. Waste POL Piping at Boiler
- McConnell AFB

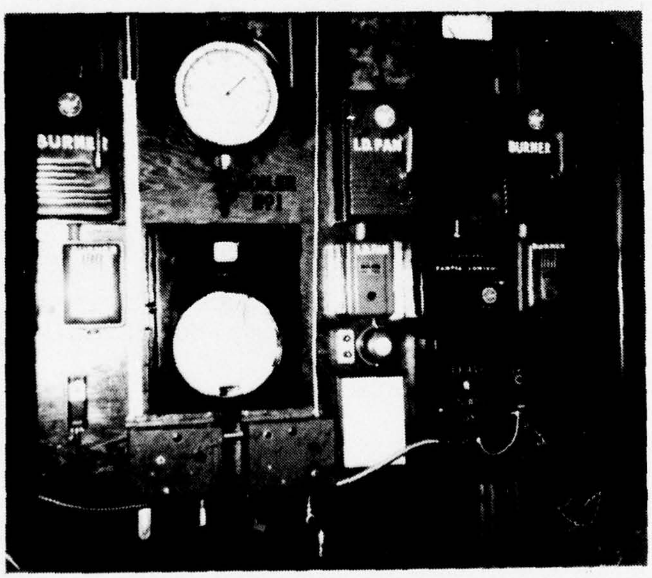



Figure 17. Control Panel
- McConnell AFB

This prototype is tied directly into a Fireye Flame System which controls the purging sequence, boiler start-up, and the waste POL unit (Figure 17). Since two boilers were modified to accommodate the Waste POL System, only one control network will be described with the second network assumed to be identical. The Waste POL Controls are tied into the Fireye Flame System at Points 1, 2, 3 and 4 (Figure 11). After the draft and fire switches have been engaged and the gas/oil switch closed, the Fireye System begins a purging sequence which checks all safety controls, ignites the pilot light, starts the flow of gas/oil and maintains flame integrity. If the flame scanner acknowledges a continuous flame in the burner, the Fire Flame Relay Contact (Figure 11) closes placing the boiler in an operational mode. Once this procedure is complete, the waste POL system can be activated in the following sequence:

(1) Manual adjustment of the pump flow rates must be accomplished for the desired waste POL/fuel oil ratio before the waste POL system is activated.

(2) The ON-OFF switch on the control panel is manually engaged providing 208 VAC to the Time Delay Relay Coil (TDR) (Figure 11). This unit provides a 1-180 second time delay before closing the TDR contact relay. POL Relay 1 (Figure 11) then energizes closing Relays RL-1-1 and RL-1-2, the POL solenoid is activated, and the pump motor engages providing waste POL flow to the burners.

(3) Low-level switches No. 1 and 2 (Figure 11), connected across points 1 and 4 open if a designated storage level is reached. This lights the low-level lamp on the control board.

(4) A check valve, after the solenoid valve and before introduction into the No. 2 fuel line, prevents backflow of No. 2 fuel oil until the waste POL line pressure can be built up to its operating feed pressure (20 to 25 psig).

## SECTION IV

## EXPERIMENTAL TESTING PROGRAM

### 1. OPERATIONAL ANALYSIS

The waste POL test plan for combusting supplemental fuels in boilers was identical for each installation; however, a pump malfunction at McConnell AFB required the utilization of gravity feed from an elevated 55-gallon drum to produce the desired experimental data. At each boiler plant, tests were conducted under two conditions: (a) using normal (pure) and (b) using contaminated POL mixed with normal fuel. All operating parameters were maintained at the same level to the extent possible during all tests.

Waste POL used in the tests was of two specific types: (a) waste JP-4 and other light petroleum fuels, and (b) conglomerates of waste lubricating oils and solvents. Each type of waste was stored separately and tested individually when possible. Care was exercised to exclude any halogenated hydrocarbons (those containing fluorine or chlorine), carbon removers, and paint strippers because of their corrosive and possibly toxic by-products. The wastes used in support of the testing effort are typical wastes generated at most USAF installations. A complete characterization and compatibility of the waste POLs and their corresponding volumes generated by each Air Force base are given in References 1 and 3.

The operational test plan employed by each of the three test facilities was as follows:

a. The waste POL system was inspected prior to activation in order to insure its construction was in accordance with the design criteria and recommended materials and equipment noted in the drawings and specifications.

b. All waste POL fuel lines were hydrostatically tested to insure system integrity.

c. The waste POL and JP-4 tanks were filled with sufficient fuel oil (No. 2 or No. 5, depending on the

base) to deactivate the low-level cut-off switch plus approximately 100 gallons. The metering pump was set at the lowest setting possible. The waste POL system was activated in accordance with the POL sequence outlined in Section III, paragraphs 1b, 2b, and 3b. Verification of flow, relay operations, check valve operation, lights and switch operations were accomplished by actual observations during starting and stopping of the system. A Davis Vapotester® was used to verify the lack of fuel vapor leaks near all newly installed plumbing. Boiler flame color and position were observed. When this test was completed, the boiler was shut down.

d. The waste POL metering pump was reset to mid-range (approximately 6 gph or 3 percent at lowest boiler fuel consumption rate). The boiler was then reactivated. A standard purge cycle was observed with stack analysis accomplished to establish a baseline for normal operation. If all observations were normal, the waste POL system was deactivated and the metering pump set to its maximum fuel flow setting (12 gph). Upon completion of this modification, the POL system was reactivated. If all operations were normal at this time, the main fuel pump was turned OFF. The purpose of this test was to insure that the automatic shutdown system engaged with the loss of the main fuel oil pump and with the waste POL system on line. Personnel were on the test site to manually shut down the waste POL system in the event of a failure in the automatic system.

e. Contaminated JP-4 and waste POLs were placed in the designated storage tanks to begin the combustion test. The boiler system was reactivated and the metering pump set to its lowest setting. The POL system was reactivated and continued in an operating mode until the waste POL was flowing into the boiler feed line. Flame color and integrity were observed at this time. The waste POL system was shut down and all plumbing once again checked for vapor leaks with the Davis Vapotester®. Cyclic operation of the waste POL was continued for a period of every 5 to 10 minutes in order to observe the flame color and position. A continuous 3-hour operation with normal boiler conditions and settings at a maximum POL percentage (26 percent McConnell, 11 percent Seymour Johnson, 4 percent Loring AFB) concluded the testing.

f. The main boiler was deactivated to once again verify automatic shutdown. If the system had failed to deactivate, manual shutdown would have discontinued testing until a safe condition was achieved.

g. Normal start-up of the boilers was accomplished except that actual burner lighting was manually overridden until stack analysis after the air purge cycle dictated a safe condition. If analysis indicated a relatively safe condition, as in the case of all three test bases, the burner light would activate. If a hazardous condition had existed, the air purge would have been extended until a safe condition was indicated. The timer would be reset to insure adequate air purge during routine operations.

h. The waste POL system was reactivated to allow for stack emissions sampling to determine pollutant concentrations. Various percentages of waste POL were tested with their respective emissions measured.

## 2. STACK EMISSIONS

The Environmental Protection Engineering Division, USAF Environmental Health Laboratory, McClellan AFB, conducted stack emissions tests at Loring, Seymour Johnson, and McConnell AFBs. These tests were performed to assess the change in stack emissions concentrations resulting from the use of waste POLs as a supplement to the FS-grade fuels and natural gas in heating plant boilers.

### a. Procedure

Each boiler/furnace was tested six times (eight times at McConnell AFB). Two tests (three at Loring) were obtained during combustion of the primary heating fuel and the remaining tests were conducted as waste POL was mixed and combusted with normal fuel oil. Boiler operating parameters were maintained at equivalent values from test to test. Fuel samples of the mix were taken at 15-minute intervals during each test from a tap located at the burner inlet. All eight fuel samples from each test were composited as one sample and then compared with the results of the emissions test. Percentages of waste POL used for experimentation in this study are given in Table 1.

TABLE 1. PERCENTAGES OF WASTE POL USED AS A SUPPLEMENT TO FUEL OIL

| BASE | WASTE | PRIMARY FUEL OIL |
|---|---|---|
| Loring AFB | 4 percent+ | 96 percent No. 2 |
| Seymour Johnson AFB | 2 percent+++ | 98 percent No. 5 |
| | 6 percent++ | 94 percent No. 5 |
| | 11 percent+ | 89 percent No. 5 |
| McConnell AFB | 16 percent++ | 84 percent No. 2 |
| | 16 percent+++ | 84 percent NG |
| | 23 percent+++ | 77 percent No. 2 |
| | 26 percent+++ | 74 percent No. 2 |

NG = natural gas
\+ = 50/50 by volume waste JP-4/lubricating oils and solvents
++ = waste JP-4
+++ = waste lubricating oils and solvents

Emissions analyzed at each test facility were those directly related to combustion efficiency and/or those commonly regulated by state and local agencies including: particulates, hydrocarbons (HC) and nitrogen oxides ($NO_x$). Iron (Fe) and lead (Pb) emissions were also studied because waste lubricating oils frequently contain these metals in higher than normal concentrations. Apparatus and materials used in the sampling can be found in Appendix C.

b. Results

Emissions are summarized in Table 2. Emissions at Loring and Seymour Johnson were, by inspection, unaffected by the use of waste POL (except Pb). This inference was supported by Students t values with a pooled estimate of the common variance (Reference 4). The t values were too small to reject the hypothesis that there was no difference in emissions with the use of waste POL.

Particulate sampling parameters are shown in Table 3. All samples were taken within ±10 percent of isokinetic flow (EPA criteria) except test 1 at Loring AFB. Particulate sample volumes also represent hydrocarbon and metal sample volumes.

## TABLE 2. EMISSIONS SAMPLING RESULTS

A. Loring AFB, 84.6 MBtu/Hr Input Cap, No. 2 Fuel Oil, HTHW, Steam Atomization
B. Seymour Johnson AFB, 19.3 MBtu/Hr Input Cap, No. 5 Fuel Oil, Water Tube, Pressure/Heat Atomization
C. McConnell AFB, 8.7 MBtu/Hr Input Cap, Natural Gas or No. 2 Fuel Oil, Fire Tube, Rotary Cup Atomization

| Test | Heat Input Percent of Cap. | Fuel Type %** Normal | Fuel Type %** Waste | Excess Air Percent | CO2 Percent | Stack Temp °F | Particulate lbs/MBtu | Hydrocarbon mg/M$^3$ | Nitrogen Oxide ppm | Lead µg/M$^3$ | Iron µg/M$^3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A | | | | | |
| 1 | 93 | 100 | 0 | 59 | 10.8 | 300 | 0.020 | 2.8 | 53 | 0.7 | 30 |
| 2 | 90 | 100 | 0 | 53 | 10.4 | 298 | 0.030 | 4.3 | 28 | 0.6 | 39 |
| 3 | 90 | 100 | 0 | 52 | 9.9 | 300 | 0.039 | 3.3 | 36 | 0.6 | 31 |
| 4 | 93 | 96 | 4+ | 41 | 8.9 | 313 | 0.033 | 3.2 | 74 | 3.1 | 56 |
| 5 | 93 | 96 | 4+ | 45 | 9.1 | 300 | 0.023 | 3.9 | 30 | 20.9 | 40 |
| 6 | 91 | 96 | 4+ | 40 | 9.0 | 298 | 0.026 | 6.1 | 24 | 20.1 | 25 |
| | | | | | | | t = 0.49 | t = 0.95 | t = 0.21 | t = 2.44 | t = 0.75 |
| | | | | | | B | | | | | |
| 1 | 78 | 100 | 0 | 72 | 9.9 | 571 | 0.125 | 6.0 | 174 | 3.1 | - |
| 2 | 78 | 100 | 0 | 65 | 9.9 | 605 | 0.096 | 15.3 | 142 | 2.7 | - |
| 3 | 80 | 98 | 2+++ | 71 | 9.9 | 595 | 0.085 | 17.8 | 139 | 2.7 | - |
| 4 | 80 | 98 | 2+++ | 69 | 9.6 | 603 | 0.106 | 4.5 | 152 | 2.6 | - |
| 5 | 78 | 94 | 6+++ | 67 | 9.5 | 571 | 0.125 | 13.6 | 98 | 17.9 | - |
| 6 | 82 | 89 | 11+ | 68 | 9.6 | 606 | 0.114 | 13.9 | 136 | 5.9 | - |
| | | | | | | | t = 0.19 | t = 0.35 | t = 1.35 | t = 0.8 | |
| | | | | | | C | | | | | |
| 1 | 94 | 100 | 0 | 93 | 7.2 | 355 | 0.027 | 17.3 | 35 | 21.5 | <72 |
| 2 | 79 | 100 | 0 | 136 | 6.1 | 348 | 0.030 | 11.5 | 54 | 2.7 | <68 |
| 3 | 120 | 100* | 0 | 70 | 6.5 | 410 | 0.005 | 5.5 | 56 | 1.2 | <61 |
| 4 | 112 | 100* | 0 | 86 | 5.6 | 379 | 0.010 | 4.3 | 63 | 1.4 | <68 |
| 5 | 116 | 84* | 16++ | 74 | 6.6 | 360 | 0.018 | 3.0 | 38 | 619.6 | 68 |
| 6 | 119 | 84* | 16+++ | 91 | 6.0 | 342 | 0.033 | 6.4 | 25 | 2465.1 | 195 |
| 7 | 64 | 74 | 26+++ | 186 | 5.0 | 324 | 0.106 | 4.7 | 62 | 3720.9 | 332 |
| 8 | 73 | 77 | 23+++ | 151 | 5.2 | 347 | 0.094 | 2.9 | 62 | 3593.9 | 407 |

* Natural gas, percent based on heat input
** By volume

\+ 50/50 by volume JP-4/lubricating oils & solvents
++ JP-4
+++ Lubricating oils & solvents

TABLE 3. SAMPLING PARAMETERS, PARTICULATES, HYDROCARBONS, AND METALS

| Test | Sample Volume $Ft^3$ (STP) | Gas Velocity (ft/min) In Stack | Gas Velocity (ft/min) In Probe | Sampling Rate Percent Isokinetic |
|---|---|---|---|---|
| | | A | | |
| 1 | 95.33 | 2027 | 2348 | 116 |
| 2 | 63.84 | 1964 | 2141 | 109 |
| 3 | 55.29 | 2028 | 1866 | 92 |
| 4 | 56.68 | 2103 | 1956 | 93 |
| 5 | 54.03 | 1950 | 1833 | 94 |
| 6 | 56.16 | 2018 | 1897 | 94 |
| | | B | | |
| 1 | 80.53 | 1700 | 1725 | 102 |
| 2 | 78.20 | 1710 | 1731 | 101 |
| 3 | 80.05 | 1728 | 1791 | 101 |
| 4 | 81.11 | 1801 | 1790 | 99 |
| 5 | 78.91 | 1746 | 1734 | 99 |
| 6 | 78.18 | 1831 | 1768 | 97 |
| | | C | | |
| 1 | 49.31 | 1999 | 1941 | 97 |
| 2 | 52.33 | 2030 | 2036 | 100 |
| 3 | 57.89 | 2203 | 2370 | 108 |
| 4 | 52.35 | 2085 | 2116 | 102 |
| 5 | 51.90 | 2055 | 2041 | 99 |
| 6 | 54.47 | 2056 | 2089 | 102 |

NOTE: See Table 2 for letter designations.

Carbon balances are presented in Table 4. These balances were used to estimate measurement accuracy of fuel flow, stack temperature, stack velocity pressure, stack moisture content, fuel density, fuel carbon content, CO and $CO_2$. Since these balances involved all eight variables (measurements), an agreement between carbon input and output of ±15 percent was considered satisfactory. Only two of 20 tests had balances outside this range.

Characteristics of the fuel and waste POL mix as fired are presented in Table 5. Specific gravity and Btu content were very slightly decreased by addition of waste POL at Loring and Seymour Johnson, but the differential was insignificant. Mixed samples could not be obtained at McConnell (sampling taps were not installed) so characteristics are given for fuel and wastes separately.

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TABLE 4. CARBON BALANCE

| | Carbon Input As Fuel | | | Carbon Output as $CO_2$ | | | Ratio |
|---|---|---|---|---|---|---|---|
| Test | Fuel lbs/hr | Percent Carbon | Carbon lbs/hr | Stack Flow CFM (STP) | Percent $CO_2$ | Carbon lbs/hr | Out/In Percent |
| **A** | | | | | | | |
| 1 | 4308 | 0.88 | 3791 | 22363 | 10.8 | 4493 | 119 |
| 2 | 4165 | 0.88 | 3665 | 22683 | 10.4 | 4389 | 120 |
| 3 | 4165 | 0.88 | 3665 | 22629 | 9.9 | 4168 | 114 |
| 4 | 4273 | 0.88 | 3760 | 23576 | 8.9 | 3904 | 104 |
| 5 | 4273 | 0.88 | 3760 | 21861 | 9.1 | 3701 | 98 |
| 6 | 4201 | 0.88 | 3697 | 22421 | 9.0 | 3754 | 102 |
| **B** | | | | | | | |
| 1 | 840 | 0.85 | 714 | 3671 | 9.9 | 676 | 95 |
| 2 | 840 | 0.85 | 714 | 3574 | 9.9 | 658 | 92 |
| 3 | 852 | 0.85 | 724 | 3654 | 9.9 | 673 | 93 |
| 4 | 852 | 0.85 | 724 | 3778 | 9.6 | 675 | 93 |
| 5 | 827 | 0.85 | 703 | 3680 | 9.5 | 650 | 92 |
| 6 | 875 | 0.85 | 744 | 3727 | 9.6 | 660 | 89 |
| **C** | | | | | | | |
| 1 | 443 | 0.88 | 390 | 3222 | 7.2 | 432 | 111 |
| 2 | 372 | 0.88 | 327 | 3253 | 6.1 | 369 | 114 |
| 3 | 10500/0* | 0.75 | 326 | 3066 | 6.5 | 371 | 114 |
| 4 | 9750/0 | 0.75 | 302 | 2948 | 5.6 | 307 | 102 |
| 5 | 8444/42 | 0.75/0.84 | 329 | 3000 | 6.6 | 368 | 112 |
| 6 | 8667/61 | 0.75/0.85 | 355 | 2956 | 6.0 | 330 | 93 |
| 7 | 301 | 0.88 | 265 | 3284 | 5.0 | 305 | 115 |
| 8 | 343 | 0.88 | 302 | 3218 | 5.2 | 311 | 103 |

* $Ft^3$/hr natural gas/lbs/hr waste (percent by Btu)

NOTE: See Table 2 for letter designations.

TABLE 5. MIXED FUEL CHARACTERISTICS

A

| Test | Waste/Fuel Percent by Volume | Gravity API | Gravity Specific | Sulfur Percent Weight | Ash Percent Weight | Water Percent Weight | Btu/Gal |
|---|---|---|---|---|---|---|---|
| 1 | 0/100 | 32.9 | 0.861 | 0.13 | 0.1 | 0.40 | 131,300 |
| 2 | 0/100 | 32.9 | 0.861 | 0.18 | 0.1 | 0.04 | 131,300 |
| 3 | 0/100 | 32.9 | 0.861 | 0.19 | 0.1 | 0.20 | 131,300 |
| 4 | 4/96 | 33.4 | 0.858 | 0.14 | 0.1 | 0.05 | 130,900 |
| 5 | 4/96 | 33.5 | 0.858 | 0.22 | 0.1 | 0.15 | 130,900 |
| 6 | 4/96 | 33.5 | 0.858 | 0.13 | 0.1 | 0.16 | 130,900 |
| | | | | B | | | |
| 1 | 0/100 | 23.0 | 0.916 | 1.79 | 0.05 | 0.11 | 137,600 |
| 2 | 0/100 | 23.0 | 0.916 | 1.83 | 0.05 | 0.12 | 137,600 |
| 3 | 2/98 | 23.0 | 0.916 | 1.73 | 0.05 | 0.16 | 137,600 |
| 4 | 2/98 | 23.0 | 0.916 | 1.76 | 0.05 | 0.15 | 137,600 |
| 5 | 6/94 | 24.6 | 0.907 | 1.60 | 0.04 | 0.14 | 136,580 |
| 6 | 11/89 | 24.6 | 0.907 | 1.72 | 0.04 | 0.12 | 136,580 |
| | | | | C* | | | |
| 1 | 0/100 | 35.1 | 0.849 | 0.08 | 0.1 | 0.1 | 130,000 |
| 2 | 0/100 | 35.0 | 0.850 | 0.22 | 0.1 | 0.1 | 130,000 |
| 7* | 0/100 | 35.0 | 0.850 | 0.17 | 0.1 | 0.1 | 130,000 |
| 8 | 0/100 | 35.0 | 0.850 | 0.17 | 0.1 | 0.1 | 130,000 |
| X | 100/0 | 26.3 | 0.897 | 0.39 | 1.25 | 2.50 | 135,530 |
| Y | 100/0 | 50.3 | 0.778 | 0.1 | 0.1 | 0.1 | 120,500 |

X = Waste lubricating oils and solvents as used in tests
Y = Waste JP-4 as used in tests
* = Mixed fuel and waste samples could not be obtained.

NOTE: See Table 2 for letter designations.

## SECTION V

## DISCUSSION

The results of this investigation have clearly demonstrated, from an operational and environmental viewpoint, the practical feasibility of combusting most waste POLs generated on Air Force bases as a supplementary fuel in heating plant boilers. Practicability was demonstrated in the program for combusting:

- Waste aviation piston-engine oil.
- Waste aviation turbine lube.
- Simple mixtures of waste aviation piston-engine oil, synthetic turbine oil, hydraulic fluid.
- Contaminated jet fuel (i.e., JP-4, JP-5).
- Contaminated gasoline (i.e., Avgas, Mogas), engine oil, synthetic turbine oil, automotive crankcase oil, and non-halogenated solvents using an oil or natural gas-fired boiler.

### 1. SEGREGATION

The waste POLs used in this study at all three installations were stored in two separate steel tanks; one for JP-4 and one for all remaining waste POLs. In order to be assured of proper segregation and the responsibilities involved in transportation, collection, and unloading, a segregation plan should be devised in accordance with TO 42B-1-23 to analyze and segregate waste POLs in order to avoid comingling waste products with halogenated hydrocarbon compounds. The combusting of these compounds result in the production of hydrogen chloride or hydrogen fluoride gas which are highly corrosive and will severely damage boiler components.

### 2. SYSTEM MODIFICATIONS

Alterations to the existing test boilers were minimal. The boilers at Loring and Seymour Johnson Air Force Bases combusting FS-grade fuel required a simple tee connection at the entrance to the burners in order to accommodate the waste POL system and to allow comingling of the two fuels at the last possible instant before injection. In the case of McConnell Air Force Base, where a dual fired system was employed, the rotary cup atomizer had

to be modified to allow for the simultaneous operation of gas or oil solenoids with waste fuels. Waste POL and No. 2 fuels were mixed prior to injection in the burner while natural gas was fed directly without constrictions. Manual control of the appropriate solenoid valves allows for simultaneous feed of the desired primary fuel with waste POL.

## 3. SYSTEM DESIGN

### a. Storage tanks

The storage tanks used in this investigation were in the 3000-to 5000-gallon range; however, the specific size was based on the volume to be combusted, burn rate, and number of tank turnovers desired due to the quantity of waste POL generated on each individual Air Force base. Consideration should be given to the filtration of waste POLs prior to storage, particularly in the case of an underground installation such as that at McConnell Air Force Base. Sediment must be evacuated by pump due to the absence of a drain valve which is present in both above ground installations at Loring and Seymour Johnson Air Force Bases. Prefiltration of waste POLs before storage will minimize down time of the tanks for cleaning and maximize the volume of fuel in the tanks for combustion.

Post filtration and screening before delivery of waste POL to the pumps is critical in order to maintain operational status. Tests have indicated that the filter-strainer combination without prefiltration requires termination of flow for cleaning every 3 to 4 days. With the introduction of a parallel filter-strainer combination (Items 5 and 6, Figures 2, 5, and 10) in the piping scheme after the storage tanks, either combination can remain on line while the remaining group is being cleaned. This configuration, coupled with prefiltration of the waste POL will result in a period of weeks between maintenance instead of days.

Storage tank installation is a prime consideration depending on numerous parameters such as the water temperature, table level, soil characteristics, fire safety, site location, etc. Both above- and belowground installations did not seem to isolate any one particular operational condition which would favor either method of construction. Both applications require adequate tank venting to allow for breathing losses due to

temperature changes and manhole covers for access. Underground installation poses less of a fire hazard due to the protection of a soil cover; however, the fuel must be gravity fed to the pumphouse configuration, as in the case of McConnell Air Force Base, changed to a submersible pump, or a pump with a sufficient suction lift to evacuate the waste POL from the tanks, must be used. The aboveground tank installation is a distinct fire hazard and must be diked with a holding capacity equal to the volume of both tanks; however, maintenance is considerably easier due to the proximity of the drain valve and gravity feed can be employed throughout the system. Underground installation requires adequate structural support against uplift and cathodic protection to abate corrosion.

Particular attention should be directed to POL installations in a cold climate. Subzero temperatures tend to increase the viscosity of waste POL resulting in a line blockage. At Loring Air Force Base, heat tapes were used to maintain the waste POL in a liquid state affording continuous flow to the burners. It is imperative that line "freezing" be minimized in order to prevent backflow of FS-grade fuel oils into the pumping system.

b. Piping

All piping, valves, and connections specified in the design of the waste POL systems were Schedule 80 black iron. In order to reduce the explosion potential of the prototype systems, the black iron plumbing used throughout is identical to that normally specified by the Air Force for use in natural gas operations which represent a vapor problem as serious as JP-4.

Appropriate consideration should be given to the location of network piping upon entrance to the heating plant. Due to the volatility of JP-4, special care is required in order to maintain a safe system free of leaks or malfunctions. Since the waste POL pipelines are in the approximate vicinity of the boilers, the large quantity of heat liberated from the boilers has a tendency to elongate this piping. Poorly installed connections could deflect or distort resulting in extremely dangerous vapor leaks. As a result of this study, it was found that the probability of vapor leaks could be drastically reduced by encasing the feed piping in the heating plant floor slab. At McConnell Air Force Base, a shallow

trench was cut out of the concrete floor to accommodate the waste POL lines directly to the boilers. After refinishing the floor slab with a ready mix concrete, a 3- to 4-foot piece of flexible pipe was used to connect the encased POL lines with the remaining gauges, solenoids, and valves required for waste POL delivery to the FS-grade fuel line. By overlaying the waste POL piping with concrete, a serious safety problem with vapor leaks is eliminated and the amount of exposed piping is minimized.

4. BOILER PERFORMANCE

Combustion tests were accomplished at all three installations to investigate the long-term effects of burning waste POLs in boilers. The testing period lasted one year with the following results:

WASTE POL COMBUSTION RESULTS

| Base | Hours | Rate | Gallons | Test Period |
|---|---|---|---|---|
| Loring AFB | 4000 | 25 GPH | 100,000 | Mar 75 - Feb 76 |
| Seymour Johnson AFB | 1350 | 12 GPH | 16,200 | Mar 75 - Feb 76 |
| McConnell AFB | 600 | 11 GPH | 6600 | Apr 75 - Apr 76 |

Although the testing period for all three bases was nearly identical in length, the wide variation in the number of hours burned resulted from system malfunctions and ambient temperature variations throughout the test period. In a colder climate such as that experienced at Loring AFB (3300 gallons of waste POL per month), the test unit was in continuous operation for nearly 10 months. At Seymour Johnson and McConnell Air Force Bases (6700 and 11,500 gallons per month of waste POL, respectively), the heating seasons are considerably shorter due to down times of several months for summer maintenance. A pump malfunction at McConnell required considerable modifications before testing resumed on 17 Feb 76; however, a total of 546 continuous problem-free hours was logged through shutdown on 4 April 76.

The performance of boilers subjected to long-term waste POL burning was of critical significance to the testing effort. At all three installations, the introduction of waste POLs and JP-4 into the burner resulted

in no adverse changes in the flame integrity. At Seymour Johnson Air Force Base there was a noticeable flame pulsation which was a direct result from the employment of a reciprocating pump with a short run of feed piping. At McConnell Air Force Base where the identical equipment was employed, but the length of pipe was 3 to 4 times as great, a damping effect of the fluid pulsations in the line perpetrated a consistent flame. In all cases, the introduction of up to 28 percent waste POLs or 16 percent JP-4 in the FS-grade fuel line resulted in a hotter and more efficient combustion. Results of this were obvious upon inspection of the boilers at McConnell. The boiler walls were stripped of residual and unburned carbon deposits while the boiler tubes were free of any evidences of corrosion. Inspection reports by the Hartford Boiler Inspection Co. for all three test facilities following shutdown for summer maintenance showed an increase in the boilers' efficiency and condition regardless of age.

## 5. AMORTIZATION

Results from this investigation have demonstrated monetary savings of up to $25,000 (Loring AFB). Since the value of amortization will vary with each Air Force base, an analysis of a proposed waste POL system as a method of disposal versus DPDO resale must be conducted by the BCE to determine its feasibility of installation. Some of the parameters which affect the installation of a waste POL system on any given base are: length of the heating season, current price of the FS-grade fuel or natural gas used, and the resale value of the waste POLs.

The material cost for the typical waste POL system used in this project was nearly $10,000. A complete breakdown of the waste POL components and their respective purchase prices can be found in Appendix D.

In order to properly evaluate the time involved for amortization, the feasibility of installing a waste POL system must be initially investigated. The quantity of waste POL combusted in the boilers depends on the quantity of FS-grade fuel combusted per month and the percentage of waste POL to be combusted without exceeding ambient air quality standards.

A x B x C = annual savings from waste POL system

A = quantity of FS-grade fuel combusted per year.
B = percentage of waste POL used.
C = price per gallon of FS-grade fuel.

This annual cost savings is then compared with the cost of reselling the same quantity of waste fuel through DPDO. If the waste POL system is more attractive in comparison with reclamation, then a system of this type should be immediately implemented. In the event that reclamation is more beneficial, the construction of a waste POL disposal facility should be discouraged.

Once the waste POL system has been selected as the more profitable disposal method, the annual cost savings is broken down into a cost per month. This value is then divided by the material cost resulting in the number of months required for amortization.

$$\frac{A \times B \times C}{12 \times D} = \text{Number of months required for payback}$$

D = material cost

It is obvious that the larger the boiler and the more waste burned per month, the more rapid the amortization period. The waste POL systems at Loring, Seymour Johnson, and McConnell Air Force Bases amortized the capital expenditure for material in 4 to 6 months after initiation of combustion.

## 6. STACK EMISSIONS

Particulate, hydrocarbon (HC), and nitrogen oxide ($NO_x$) emissions from the Loring Air Force Base boiler were not appreciably affected by using a fuel mixture containing 4 percent by volume waste POLs and 96 percent No. 2 fuel oil. Standard Environmental Protection Agency sampling procedures for the determination of emissions were used at all three test facilities. The waste POL consisted of equal volumes of waste JP-4 and waste lubricating oils and solvents. At Seymour Johnson Air Force Base, the identical emission constituents at Loring Air Force Base were relatively unaffected by a conglomerate mixture containing 11 percent waste POL and 89 percent No. 5 fuel oil. The 11 percent waste POL mixture was composed of equal quantities of waste JP-4 and various grades of waste lubricants. Emissions were also unaffected by 2 percent lubricating oils and solvents with

98 percent No. 5 fuel oil and 6 percent waste JP-4 with No. 5 fuel oil.

Particulate emissions from the McConnell Air Force Base boiler were increased when 16 percent of either type of waste POL was used with natural gas. These emissions were also increased when 23 percent waste lubricating oils and solvents was comingled with No. 2 fuel oil. Iron (Fe) and lead (Pb) emission concentrations were increased at least 5 and 160 times, respectively, when 26 percent waste lubricating oils and solvents was used. The waste POL contained 40 times more Pb (16 vs 0.4 ppm) than the pure No. 2 fuel oil. Lead emissions were increased nearly 470 times (619.6 versus 1.3$\mu g/m^3$) when 16 percent waste JP-4 was used with natural gas. The waste JP-4 contained 1 ppm Pb.

At Loring and Seymour Johnson Air Force Bases, a slight increase in Pb emissions was noted; however, the data obtained was inconclusive due to analytical interferences from other compounds and too few samples. Particulate emissions were increased as the percentage of waste POL to pure fuel increased. For example, 4 percent waste POL had no detectable effect on particulate emissions at Loring Air Force Base, but 16 percent waste POL at McConnell Air Force Base significantly increased particulate emissions. These units had almost identical particulate emissions in pound/MBtu, under similar operating conditions, burning only No. 2 fuel oil. When the percentage of waste POL was increased to 23 and 26 percent at McConnell, the increase in particulate emissions was even more spectacular. Particulate emissions increased from an average of 0.029 lb/MBtu when 100 percent No. 2 fuel oil was used, to 0.094 and 0.106 lb/MBtu when 23 and 26 percent waste POL was added to the No. 2 fuel oil.

The type of waste POL also significantly influenced particulate emissions. At McConnell Air Force Base, 16 percent waste JP-4 and 16 percent waste lubricants and solvents were each used with natural gas. The 16 percent waste JP-4 only moderately increased emissions from an average of 0.005 lb/MBtu to 0.018 lb/MBtu while 16 percent waste lubricating oils and solvents significantly increased particulate emissions to 0.033 lb/MBtu.

Of the emissions evaluated, only particulates and nitrogen oxides were subject to regulation. Metal emissions are not regulated at the federal or state levels (Reference 5). None of the facilities, including McConnell Air Force Base where particulate emissions were significantly increased, violated federal or state codes.

Operating limitations were encountered that prevented the use of more than 4 percent waste POL at Loring Air Force Base and less than 16 percent at McConnell Air Force Base. At Loring, 25 gallons per hour (GPH) waste was the maximum waste pumping capacity available. At McConnell, the only capacity available was 12 GPH.

## SECTION VI

## CONCLUSIONS AND RECOMMENDATIONS

Air Force waste POL can be used in significant quantities as a supplement to heating plant fuel without causing any detectable difference in regulated emissions of particulate matter, nitrogen oxides and hydrocarbons. Up to 11 percent by volume of waste POL can be added to No. 5 fuel oil and 4 percent by volume to No. 2 fuel oil without causing any detectable changes in boiler emissions (except Pb/Fe).

Up to 16 percent waste POL can be added to natural gas (in boilers with appropriate fuel injection systems) and up to 26 percent waste POL can be used with No. 2 fuel oil without violating emission standards. (Most agencies regulate particulate matter, $NO_x$ and $SO_2$.) The addition of these amounts of waste POL will significantly increase particulate emissions over No. 2 fuel oil or natural gas alone. However, the resulting emissions will be below most current standards.

This study confirmed the obvious conclusion that a relatively clean burning fuel (waste JP-4) mixed with a dirty burning fuel (No. 2 to No. 6 fuel oil) will not adversely affect regulated emissions. Conversely, a relatively dirty burning fuel (waste lubricating oils) will adversely affect particulate emissions if mixed with a clean burning fuel but will not necessarily cause violations of emission standards.

Sulfur dioxide, a regulated emission, will not be adversely affected by waste POL since the sulfur content of waste POL is generally lower than normal fuels except natural gas.

Long-term combustion of waste POLs had no noticeable effect on boiler operations. Due to the relatively more efficient combustion of FS-grade fuel or natural gas with waste fuels, boiler operational parameters such as steam production, heat transfer, and flame integrity, have remained constant or have improved.

Since the combustion of waste POLs has been successfully proven in this study to be a practical and economical disposal method, it is imperative that all Air Force

bases implement a similar system if a cost analysis dictates a larger monetary return than resale and eventual reclamation. Prior analysis by the BCE must be completed before a break-even point is reached and the expected amortization period can be calculated.

The following methods of implementation are recommended for proper installation of a waste POL system:

a. A cost analysis is conducted to determine whether a waste POL system is economically feasible.

b. Site selection should then be determined with inputs from the BCE and fire chief.

c. An environmental impact assessment should be prepared by the OPR.

d. Civil Engineering should begin design and construction of the waste POL system.

e. A segregation plan should be devised in accordance with TO 42B-1-23.

f. Stack emissions tests are then taken by the base Bioenvironmental Engineer to determine the allowable percentage of waste POL to FS-grade fuel without exceeding federal or state ambient air quality standards.

g. Once the percentage of waste POL has been identified, continuous combustion of waste POLs should begin.

It is highly recommended that all personnel associated with the collection, transportation and storage of the waste POLs be thoroughly instructed as to the need for the proper segregation of halogenated hydrocarbons. Combustion of these compounds, even in small quantities, produce highly corrosive a/o toxic by-products. Their inclusion with the waste POLs to be combusted should be discouraged.

## APPENDIX A

## CONCEPTUAL FLOW DIAGRAM

Figure A-1 - Conceptual Flow System Scheme Waste POL Disposal System

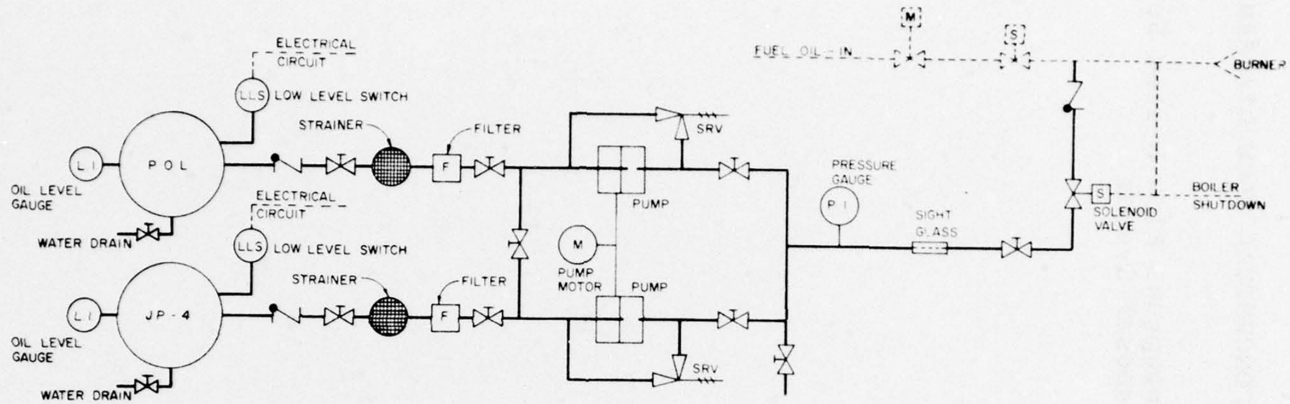


Figure A-1. Conceptual Flow System Scheme Waste POL Disposal System

APPENDIX B

CONCEPTUAL CONTROL DIAGRAM

Figure B-1 - Conceptual Electrical Circuit Waste POL Disposal System.

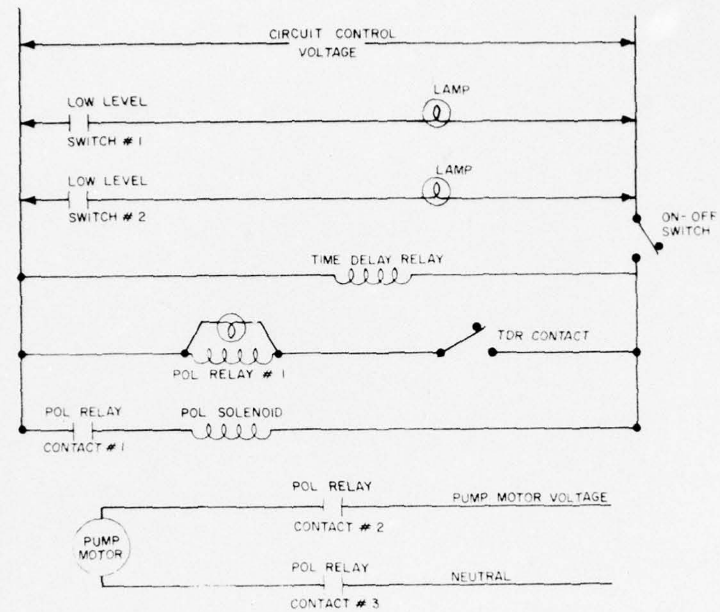


Figure B-1. Conceptual Electrical Circuit Waste POL Disposal System

# APPENDIX C

## APPARATUS AND MATERIALS

1. Particulate Emissions

Particulate samples were obtained with equipment constructed in accordance with the publication Construction Details of Isokinetic Source-Sampling Equipment, APTD-0581, US Environmental Protection Agency, April 1971. Sampling and analysis were conducted in accordance with Test Methods given in the Appendix to Title 40, Code of Federal Regulations, Part 60 (Reference 6).

2. Hydrocarbon Emissions

Hydrocarbon samples were obtained with the isokinetic source-sampling equipment in conjunction with particulate tests. One Greenburg-Smith® impinger containing 500 grams of 60/80 mesh activated carbon was added to the impinger train. Hydrocarbons were extracted from the glass fiber filter, the water and the activated carbon by the method given in Manual of Methods for Chemical Analysis of Water and Waste (Reference 7). The extract was analyzed with a Beckman IR-12 infrared spectrophotometer for total hydrocarbons.

3. CO, $CO_2$ and $O_2$

Samples were taken each 15 minutes by Orsat. Each reported test value represented eight measurements.

4. Metals

Metals contained on the glass fiber filter (taken isokinetically) and in the fuel were determined qualitatively by emission spectroscopy and quantitatively by atomic absorption. The collection of Pb on the glass fiber filter was equivalent to the method recommended in Appendix I to the criteria document, Occupational Exposure to Inorganic Lead (Reference 8).

5. Nitrogen Oxides

Sampling and analysis were conducted in accordance with Method 7, Determination of Nitrogen Oxide Emissions from Stationary Sources, Appendix to Title 40, Code of Federal Regulations, Part 60 (Reference 6).

6. Fuel Characterization

Fuel was characterized by the following methods:

a. API gravity - ASTM 287

b. Ash content - ASTM 80.01

c. Sulfur - ASTM 1662

d. Btu value - ASTM D2382

e. Metal content - Emission spectroscopy and atomic absorption.

APPENDIX D

MATERIAL COST ESTIMATE (TYPICAL BASE)

| | | | |
|---|---|---|---|
| Level Gauge | 2@ | 137.50 | $ 275 |
| Storage Tanks | 2@ | 2,200.00 | 4,400 |
| Check Valve | 4@ | 41.25 | 165 |
| Gate Valves | 9@ | 13.50 | 122 |
| Strainer | 2@ | 27.50 | 55 |
| Filter | 2@ | 10.50 | 21 |
| Pump (with SPUS) | 1@ | 692.00 | 692 |
| Pressure Gauge | 2@ | 28.50 | 57 |
| Sight Glass | 1@ | 63.00 | 63 |
| Solenoid Valve | 1@ | 31.50 | 32 |
| Low Level Switch | 2@ | 70.00 | 140 |
| Time Delay Relay | 1@ | 45.00 | 45 |
| Relay | 1@ | 22.00 | 22 |
| Switch | 1@ | 1.50 | 2 |
| Lamp & Holder | 3@ | 2.40 | 8 |
| Relay Box Enclosure | 2@ | 14.30 | 29 |
| Misc (Pipe, wire, etc) | | | 2,000 |
| | | | $8,128 |



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